Chemical and Petroleum Engineering, Vol. 33, No. 5, 1997

WORK OF MASHPROEKT NPP AND ZARYA PRODUCTION ASSOCIATION IN CONVERSION OF SHIP GAS TURBINE ENGINES

V. I. Romanov, V. Ya. Kazanovich, and A. N. Stashok

UDC 621.438:629.12

The first converted ship gas turbine engines (GTE) were introduced into service in industry for supplying power to electric generators of portable and stationary electric power stations at the beginning of the 1970s. Electric trains of the Mayak type with a power plant with a power of 4000 kW and floating electric stations of the Severnoe siyanie type with a power plant consisting of two gas turbine generators (GTG) with a power of 12,000 kW, with utilization of heat, were developed. The steam produced was used in technological applications. Stationary electric power stations with GTG of 12,000 kW were constructed at Baikonur, Nadym, Nebit-Daga, etc. In 1975, a government decree on the application of ship gas turbine engines for gas-pumping systems of transmission pipelines was issued. This marked the start of active cooperation of the Mashproekt NPP and Zarya Production Association (PO) with Gazprom Russian Joint-Stock Company (RAO) in conversion of these engines.

The first series-produced gas-pumping systems GPA-10 with a power of 10 MW were supplied in 1979 to compressor stations of transmission gas pipelines. However, the main developments of Mashproekt NPP were intended for the ships of the naval fleet. From its foundation in 1954 up to now the Mashproekt NPP developed four generations of engines with a power of 100 to 25,000 kW which were then used for developing over 50 types of power plant for almost all types of ships and craft, including vessels and craft with dynamic floating principles. Up to 1991, 90% of the volume of work of Mashproekt NPP was directed at developing new and improving standard ship power systems.

In 1991, due to a large decrease in the number of military orders and taking into account the experience with the service of ship GTE in national economy, the following main direction of development was specified: installation of effective gas-turbine systems in the compressor and gas-pumping stations and electric power stations. These turbine systems included the GTE of the third and fourth generations, with the parameters presented in Table 1 (according to the ISO position the temperature of the entry is 15°C). The engines can operate with liquid or gas fuel.

The main customer for the engines and equipment developed by Mashproekt NPP is the Gazprom RAO who ordered more than 700 engines, 400 of these are in service. At present, the total operating time of the engines is longer than 14 million h.

Almost 250 engines came to the end of their design life but are still in operation. The service life to a major overhaul, depending on the type of GTE, was specified in the range from 20,000 to 30,000 h: the total service life 40,000-60,000 h, respectively. At present, there are gas pumping systems which have been operating for more than 60,000 h without a major overhaul. Up to 80% of the gas turbine engines have been sent for a major overhaul and then returned to service with the operating life set at the previous level. Using the service results, the design of the gas turbine engines is being improved to increase the economic efficiency and reliability.

In 1988 series production started of more reliable and economic GPA-16 systems with the DZh-59L2 engine of the second generation with a power of 16 MW (efficiency 39%). Up to now, the Zarya PO have manufactured more than 120 systems of this type.

In accordance with an order from Gazprom RAO, the Mashproekt NPP developed a GU-59 gas generator for replacing the Avon gas generators of Coberra-182 gas pumping stations (Great Britain) which came to the end of their operating life. The GU-59 gas generator, used at the Bogadinskaya compressor station, Surguttranzgas PO, has been operating for more than 35,000 h and continues to work without malfunction.

A GTG-15 gas turbogenerator with heat recycling and with a power of 15.4 MW was designed and supplied to the Mozyrsk Oil Processing Plant (Belarus). The electric energy and steam are used for the requirements of the plant. Since the end of 1995 the GTG-15 has operated for about 5000 h.

Translated from Khimicheskoe and Neftegazovoe Mashinostroenie, No. 5, pp. 66-68, September-October, 1997.

0009-2355/97/3305-0571$18.00

TABLE 1

Type of GTE	Power, kW	Efficiency, %	Degree of increase of pressure	Consumption of air, kg/sec	Temperature of gas at outlet, °C	Weight of GTE with the frame, t
GT 2500	2850	28,5	12,0	14,9	435	1,5
GT 3000	3000	30,5	13,5	16,4	440	2,5
GT 6000	6700	31,5	13,9	31,0	420	3,5
GT 150000	17 500	35,0	19,6	71,3	433	9
GT 25000	27 500	36,0	21,8	87,6	475	14

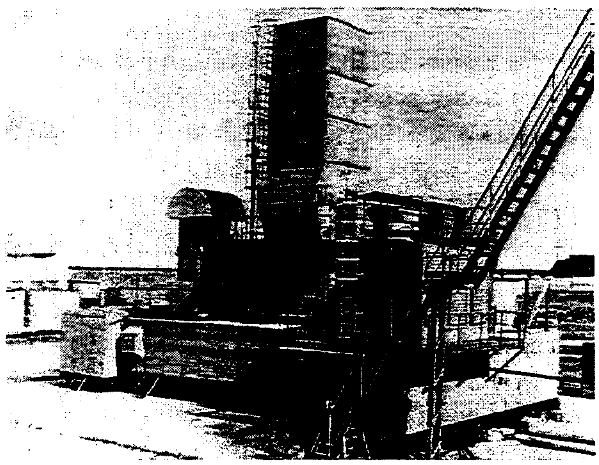

Fig. 1. Block-container 6 MW electric power station.

In 1991, the Gazprom RAO and Ukrgazprom compressor stations started to receive the gas pumping systems fitted with third generation engines. These engines are characterized by higher parameters of economic efficiency, reliability, and good weight and dimensional characteristics. They were used as a basis for developing advanced gas pumping systems and gas turbine engines with a power of 2.5, 3, 6, 10, 16, and 25 MW in the block-container form (Figs. 1 and 2). The blocks of the aggregates and the container blocks, comprising the gas pumping system (GTG) and including the auxiliary equipment, assembled in the plant, with the systems resulted in a large decrease of the time and cost of construction of compressor stations (CS) in remote and low-populated regions. The parameters of the gas pumping system are presented in Table 2.

The second important application of the new engines in gas industry is the modernization of the gas pumping systems and replacement of obsolete engines while maintaining the structure of the CS. This measure greatly increases the economic efficiency of the CS at the minimum cost of modernization. For example, the use of a DG 90 third generation gas turbine engine (modification GT 15,000) in the GTK-10-4 system makes it possible to save 20.6 million m^3 of gas per system per year, and the DN 80 engines of fourth generation (modification GT 25,000) in the GPA 25/76 system instead of GTN 25 (Nevskii Zavod PO) saves 16.3 million m^3 of gas. The DN 80 gas turbine engine, which replaced the GTN 25 at the Sofievskaya CS (Cherkask region, Ukraine), is shown in Fig. 3.

At present, the engines of the third and fourth generations, developed by Mashproekt NPP, are installed in many CS (Table 3).

The supply of engines, developed by the Mashproekt NPP, to the gas pumping systems is provided by M.V. Frunze Sumy Machine Construction Scientific–Production Association (SMNPO) Joint-Stock Company (AO).

One of the most important directions of work in the development of efficient engines for industry is the increase of the ecological parameters of the engine. The work to reduce the extent of harmful emission of NO_x and CO in the plant has been carried out intensively since 1991. In the past, the level of emission of engines of the basic series was halved. At present, work is being completed on the development of a combustion chamber which, using the "dry" method, makes it possible to reduce the level of NO_x to 70 mg/m^3 and CO to 100 mg/m^3. The tests - ecological injection of water and steam into the combustion chamber of the engine - show that the level of NO_x is reduced to 35-40 mg/m^3.

TABLE 2

Type of gas pump-system (GPS)	Power, MW	Drive engine	Efficiency, %	Air flow rate, kg/sec	Frequency of rotation of the power turbine, rpm
GPA-2,5	2,5	GT 2500	27,7	14,1	1300
GPA-3	3,0	GT 3000	29,5	16,4	9700
GPA-6	6,3	GT 6000	30,5	29,7	8200
GPA-10	10	GT 10000	35,0	36,6	4800
GPA 16	16	GT 16000	34,0	70,3	5300
GPA-25	25	GT 25000	35,0	85,9	3600

TABLE 3

Type of GTE	Compressor station	Plant-customer	Number of GTE
GT 6000	Oktyabr'skaya Gavrilov Yam Kupyanskaya	Mostransgaz Mostransgaz Ukraine	3 1 5
GT 15000	Bogandinskaya Turtasskaya	Surgutgazprom Surgutgazprom	6 3
GT 25000	Sofievskaya	Ukraine	1

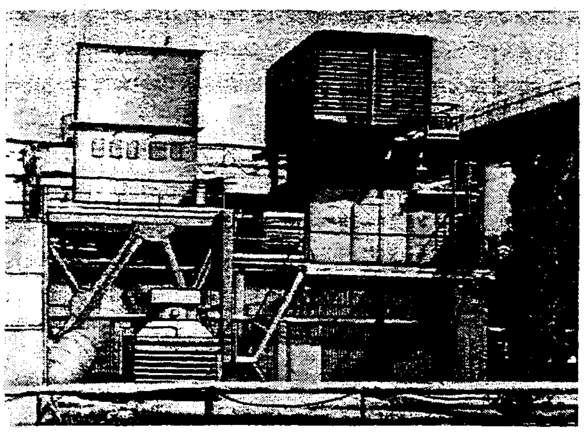

Fig. 2. GPA-16 block gas-pumping system.

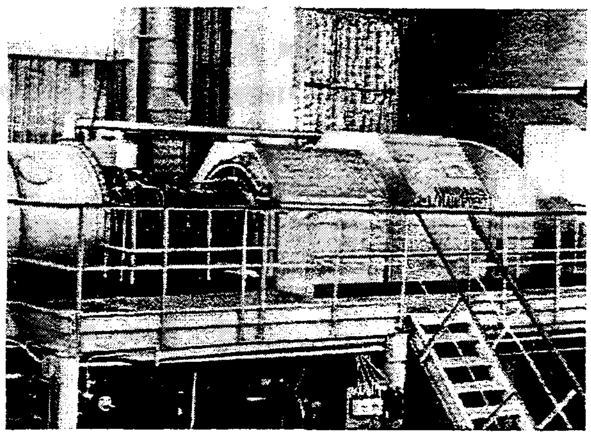

Fig. 3. DN 80 engine (modification GT 25,000) at the Sofievskaya CS.

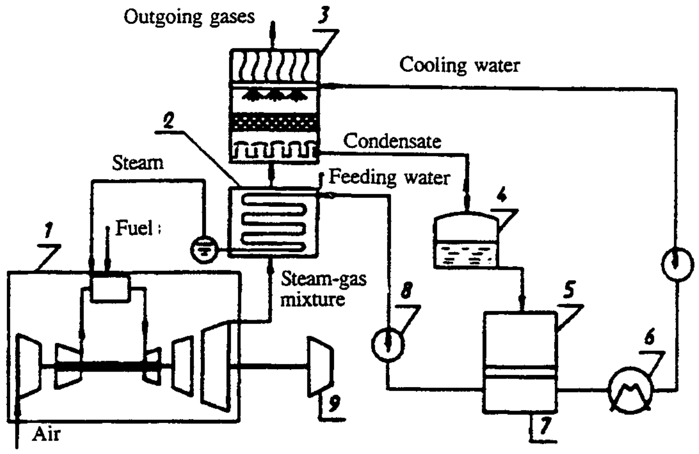

Fig. 4. Principal diagram of GPU-16K: 1) gas turbine engine; 2) boiler-economizer; 3) contact steam condenser; 4) condensate collector; 5) unit for cleaning the condensate; 6) external cooler; 7) container with feeding water; 8) pump; 9) gas booster.

The Mashproekt NPP was the first to develop and use the method of utilization of heat of outgoing gases in main ship gas turbine engines. Consequently, the fuel consumption was reduced by 20-25% in comparison with the equipment using the simple cycle. These gas turbine engines were fitted to the Slava missile cruisers and Kapitan Smirnov container ships.

Utilizing the experience obtained in developing and using ship energy power systems with heat utilization, the Mashproekt NPP have developed a series of industrial highly economic gas turbine generators, steam gas equipment (SGE), and equipment with the energy injection of steam into the flow section of the engine for application in power engineering and oil and gas industry.

Technical Characteristics of GTG

Type	GTG-2,5	GTG-6	GTG-15	GTG-16	GTG-25
Power, MW	2,5	6	15,4	16	25
Drive:					
type	GT 2500	GT 6001	GT 16000	GT 15000	GT 25000
power (according to ISO), MW	2,85	6,7	16,3	17,5	27,5
efficiency (according to ISO), %	28,5	31,5	31	35	36
Thermal power of the boiler,* MW	5,15	10,16	27,12	25,6	36,05
Steam consumption, t/h	5,35	10,7	25,7	25,6	36,4/6,9 †
Steam pressure, MPa	1,6	1,8	1,6	2,2	3,6/0,26 †
Steam temperature, °C	330	320	317	365	385/198 †
Thermal efficiency of equipment* with heat utilization, %	82,6	83,5	80,9	85	85,4

*With the gas heater of mains water for household applications.

†The boiler using two pressures.

Technical Characteristics of SGE

Type	SGE-22	SGE-35	SGE-45	SGE-70
Composition				
turbine	GT 15000+ +PT6	GT 25000+ +PT2	2GT 15000+ +PT2	2GT 25000+ +PT20
boiler	KUP31000*	KUP31000*	2xKUP31000*	2xKUP31000*
Power, MW				
SGE	21,5	34	43	68
GTE	15,5	24,25	2x15,5	2x24,25
steam turbine	5,97	9,73	11,94	19,46
Steam consumption, t/h	25,6	39	2x25,6	2x39
Gas temperature behind boiler, °C	165	160	165	160
General efficiency of equipment, %	43,6	47,7	43,6	47,7

*Prototype.

The most interesting of the systems described here is the project of the GPU-16K gas-pumping system designed for CS of transmission gas pipelines. The equipment operates as follows (Fig. 4). The heat of the gases leaving the engine is utilized in the steam boiler. The resultant steam is injected into the combustion chamber of the engine and mixed with the gas flow. The energy of the steam-gas flow is utilized for driving the compressors of the engine and producing useful power in the turbine of the booster. Behind the boiler, the steam-gas mixture is cooled down in a contact condenser. The cooling water and the separated condensate are discharged into a condensate collector, cleaned to remove harmful impurities, cooled in the external cooler, and returned to the boiler.

Technical Data of Combined Gas Turbine Systems with Injection of Steam into the Flow Part of the Engine

Type of SGE	GPU-16K	GTG-25C
Composition:		
turbine part of equipment	T6000	T15000
boiler part of equipment	KUP27000*	KUP31000†
Power of SGE, MW	16	25
Steam consumption, t/h	11	25,6
Temperature of gas behind the boiler, °C	150	157
Total efficiency of equipment, %	43	43

*In development stage.
†Prototype.

The elements of the GPU-16K system are being developed in experimental equipment with a power of 25 MW which has been operating since 1994 for more than 1000 h in the steam injection regime. It is already possible to note the stable operation of equipment under all conditions and, most importantly, the low level of harmful emission of NO_x (40 mg/m^3 at 15% O_2). On the basis of the test results it is concluded that a new type of highly efficient power systems for various applications has been developed.

In the near future, the organization will complete the development of engines of the fourth generation with a power of 10, 20, and 110 MW, and will form a scientific and technical section for the fifth generation engines.